Clinical review

Poliomyelitis and the postpolio syndrome

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In the first half of the 20th century, poliomyelitis was widely feared. It often struck without warning, was highly contagious, and affected large, young populations, causing prolonged or permanent flaccid paralysis or death. There are arresting and disturbing accounts of the explosive nature of polio epidemics and the response of communities to these outbreaks.[1] The effective control of poliomyelitis throughout most of the world has been a remarkable story of scientific and social progress. However, "wild" poliomyelitis is still endemic in parts of sub-Saharan Africa and the Indian subcontinent, and it continues to occur sporadically elsewhere. In addition, there is a small incidence of vaccine induced polio in infants and adults. Global eradication remains a goal of the World Health Organization and of public health policies throughout the world, with the eventual discontinuation of routine immunisation.[2–4]

Acute poliomyelitis is now rarely encountered in the United Kingdom, but "imported" poliomyelitis still occurs and it is necessary to distinguish acute poliomyelitis from other causes of acute flaccid paralysis. Despite the obvious success of preventive policies, many patients who had poliomyelitis experience late functional deterioration after periods of prolonged stability—the so called postpolio syndrome. The patterns of disability and their management present unique challenges to the multidisciplinary rehabilitation team.

Summary points

- Despite the success of the World Health Organization's policy for global eradication of poliomyelitis, poliomyelitis is still endemic in some countries and vaccine associated poliomyelitis continues to occur
- The eradication policy involves intensive mass immunisation, but concerns about vaccine associated poliomyelitis have led to increased use of inactivated polio vaccine, which is injected rather than given orally, in immunisation strategies
- Other causes of acute flaccid paralysis, such as Western Nile encephalitis, may mimic acute poliomyelitis
- Postpolio syndrome is characterised by fatigue, weakness, joint and muscle pain, and worsening functional abilities
- Development of postpolio syndrome does not inevitably imply progressive deterioration, but management requires a multidisciplinary approach with provision of appropriate exercise regimens and suitable medical or orthotic support

Methods

This review is based on personal experience and the advice of numerous physicians and surgeons, in particular the combined expertise of my colleagues at the Lane Fox Unit at St Thomas' Hospital. In preparing the article, I accessed archive literature, departmental review papers,[5 6] the library, Medline searches via Ovid, and websites of patient groups involved in the care of people with polio and postpolio functional deterioration.

The disease

Poliomyelitis is caused by an enterovirus of high infectivity whose main route of infection is via the human gastrointestinal tract. There are three subtypes of poliovirus, but, before the introduction of vaccine, type 1 accounted for 85% of paralytic disease. Infection is oral, and the virus multiplies in the pharynx and intestine for one to three weeks before it is contained by a local immune response or a viraemic phase occurs. The virus continues to be excreted in the saliva for two or three days and in the faeces for two to three weeks. The infection rate is extremely high, but it is probable that 95% of all infections are either asymptomatic or characterised by an abortive flu-like illness. In the temperate climates of the northern hemisphere, epidemics of polio occurred most commonly during the summer months, and the incidence was greatest where children bathed together.

Acute illness

After the minor, flu-like illness, patients develop a meningitic phase as the virus reaches the central nervous system. This is characterised by high fever with pharyngitis, myalgia, anorexia, nausea, vomiting, head-

P+ *Extra references to relevant articles are on bmj.com*

ache, and neck stiffness. The factors favouring the development of spinal poliomyelitis are unclear, but it has been suggested that physical activity and intramuscular injections during the minor illness may be important. The onset of spinal poliomyelitis is associated with myalgia and severe muscle spasms, with the subsequent development of an asymmetrical, predominantly lower limb, flaccid weakness that becomes maximal after 48 hours.

A purely bulbar form with minimal limb involvement also occurs, particularly in children, and was more common in those whose tonsils and adenoids had been removed. This form of polio has a particularly high mortality because of vasomotor disturbances such as hypertension, hypotension and circulatory collapse, autonomic dysfunction, dysphagia, dysphonia, and respiratory failure. Poliovirus may also cause an acute encephalitis.

Diagnosis

The cerebrospinal fluid shows increased protein content and pleocytosis with normal glucose concentration, but the virus is more commonly isolated from the nasopharynx or stools. In the absence of a viral isolate, serological diagnosis can be established by neutralisation of sera against paired antigens of the three viral serotypes, which also allows differentiation of wild type from vaccine induced disease. Molecular diagnosis with the polymerase chain reaction is now the technique of choice for identifying poliovirus serotype and for differentiating between wild and vaccine strain poliomyelitis.[7]

Differential diagnosis—Acute flaccid paralysis is associated with infection by other enteroviruses (including coxsackievirus A7 and enterovirus 71), tickborne encephalitis, and by flaviviruses (including Japanese encephalitis and, more recently, West Nile virus).[8] The differential diagnosis of asymmetric motor flaccid paralysis includes Guillain-Barré syndrome,[9] acute intermittent porphyria, HIV neuropathy, diphtheria, and *Borrelia bergdorferi* infections (Lyme disease), and disorders at the neuromuscular junction such as myasthenia and botulism (see box 1).[10]

Treatment of acute attack

All patients should be put on strict bed rest to prevent extension of the paralysis. Pain relief and frequent passive movements prevent contractures and joint ankylosis. Acute respiratory failure may develop rapidly, requiring intubation and intermittent positive pressure ventilation. If prolonged ventilation is needed or there is coexisting bulbar weakness, tracheostomy may be necessary to protect the airway.

During the first few weeks of mobilisation, the main aim of management is to prevent deformity by stretching and splinting of affected limbs. Intensive physiotherapy is directed towards retraining affected muscles to regain strength and function and providing appropriate orthoses to compensate for loss of function, facilitate mobility, and prevent undue wear and tear.

Immunisation and eradication

Prevention

The demonstration, in 1949, that poliovirus could be successfully propagated in non-neuronal cell cultures led to the award of the Nobel Prize to Enders, Robbins, and Weller. This was the catalyst for the development of effective immunisation against poliomyelitis, initially by Jonas Salk and subsequently by Albert Sabin. The introduction of the Salk trivalent inactivated polio vaccine (IPV) in 1956 for routine immunisation reduced the incidence of polio in the United States by more than 90%. It is given by injection and stimulates serum IgM, IgG, and IgA, but not secretory IgA, immunity being induced by antibody transuding into the oropharynx.

Sabin trivalent oral live attenuated polio vaccine (OPV) replaced the Salk vaccine in 1962. This is composed of live attenuated strains of polioviruses 1, 2, and 3 grown in cell culture. The advantages over the Salk

Box 1: Causes of acute flaccid paralysis

In countries where polio is currently, or was recently, endemic every case of acute flaccid paralysis should be notified regardless of the likely cause. Two stool specimens should be collected within 14 days of the start of paralysis, and virus isolation should be performed in a qualified laboratory.

Infection

- Viral
  Enterovirus—poliomyelitis (wild and vaccine associated), enterovirus 71, coxsackievirus A7
  Flavivirus—Japanese encephalitis, West Nile virus
  Herpesvirus—cytomegalovirus, Epstein-Barr virus, varicella-zoster virus
  Tick borne encephalitis
  HIV related—associated with opportunistic infections
  Other neurotropic viruses—rabies
- Borrelia
- Mycoplasma
- Diphtheria
- Botulism

Neuropathy

- Acute inflammatory polyneuropathy
- Acute motor axonal neuropathy
- Critical illness neuropathy
- Lead poisoning
- Other heavy metal poisoning

Spinal cord

- Acute transverse myelitis
- Acute spinal cord compression
- Trauma
- Infarction

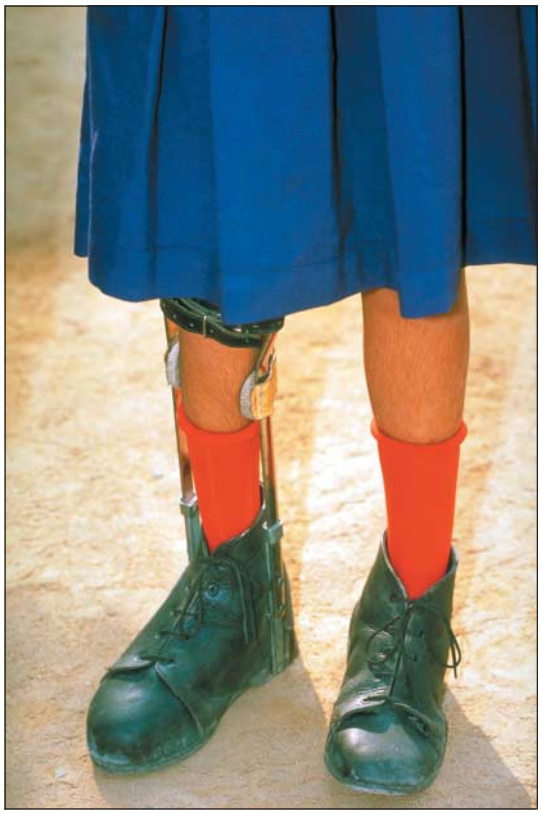
Neuromuscular junction

- Myasthenia gravis

Muscle

- Polymyositis
- Viral myositis
- Post-infectious myositis
- Critical illness myopathy

Functional



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In most cases of postpolio syndrome, underlying weakness and skeletal deformity predisposes to functional deterioration

vaccine were that it was cheap, could be administered orally, and caused an active attenuated infection of the oropharynx and intestinal endothelium, stimulating local secretary IgA in addition to serum antibody production. Furthermore, the attenuated virus is excreted in the faeces, leading to herd immunity. Complete immunisation with the oral vaccine has conventionally included four doses routinely given at 2, 4, and 6-18 months of age with a booster at 4-6 years.

After the introduction of mass vaccination programmes in the late 1950s and early '60s the incidence of paralytic poliomyelitis was dramatically reduced, but global vaccination was not possible. Furthermore, because the oral vaccine results in the excretion of live virus, there is a small incidence of vaccine associated paralytic poliomyelitis in unimmunised direct contacts (such as those who change the nappies of infants who have recently received the vaccine), especially if they are immunosuppressed. In North America, Europe, Japan, Australia, and New Zealand, the ongoing occurrence of vaccine associated paralytic poliomyelitis and the elimination of wild type polio has led to increased use of the Salk vaccine, culminating in the present recommendations that the Salk vaccine completely replace the oral vaccine in immunisation schedules.[11 12]

Policies for global eradication

The launch of the WHO global eradication initiative in 1988 has led to a dramatic reduction in the number of cases worldwide, from 350 000 in 1988 to 900 cases in 2003. Polio is considered to be endemic still in six countries (Nigeria, India, Pakistan, Niger, Afghanistan, and Egypt), although imported wild disease occurs in seven other African countries. A recent alarming epidemic has occurred in Nigeria. A case count register is available on the WHO website.

The present global eradication policy is based on a four point strategy:

- *Routine immunisation* to ensure high infant coverage in the first year of life. Regions where eradication has been achieved must continue high levels of immunisation to prevent the re-establishment of poliovirus if it is imported
- *Mass immunisation campaigns*—During "mass immunisation days" routine immunisation is supplemented by the provision of two further doses of oral vaccine to large numbers of children under 5 years old
- *Continuous surveillance* undertaken by national, regional, and global laboratories aims to identify all cases of acute flaccid paralysis regardless of the underlying cause; the diagnosis of polio is subsequently confirmed by the genomic sequencing of wild type poliovirus
- *Mopping up campaigns* are used in countries where the final pockets of poliovirus transmission have been identified. These campaigns involve door-to-door immunisation in high risk districts where the virus is still thought to be circulating. They are concentrated particularly where access to health care is difficult and there is high population density and mobility, poor sanitation, and low routine immunisation coverage.[13]

Despite the success of this policy, considerable difficulties remain and new outbreaks continue to occur. In particular, it is difficult to provide sufficient heat-stable oral vaccine to ensure adequate seroconversion in tropical populations and to prevent the occurrence of vaccine associated paralytic poliomyelitis. This has led to the suggestion that the oral vaccine should be abandoned in favour of the injected Salk vaccine. The cost of global eradication remains enormous, and there are real concerns that the political determination to maintain eradication policies may be eroded by the success of the campaign. The WHO continues to warn of the increasing worldwide vulnerability to polio if the mass campaign is discontinued.

Postpolio syndrome

After a period of prolonged stability, many patients with residual impairments following paralytic poliomyelitis develop new disabilities. These late changes were recognised and defined medically in terms of progressive muscular atrophy, weakness, pain, and fatigue, but most patients were more particularly aware of late functional deterioration manifest as impairment of activities of daily living, mobility, upper limb function, and respiratory capacity.[14–18]

The nature of the condition remains controversial, with most definitions continuing to indicate that the new symptoms and signs should be unrelated to any orthopaedic, neurological, respiratory, or systemic medical illness. Studies of this condition have suggested that new wasting and weakness is due to a distal degeneration of motor units that had been affected by poliomyelitis and which is associated with age and overuse or disuse.[14 19] There is a contradiction, however, as most patients who experience postpolio functional deterioration have considerable existing orthopaedic and neurological impairment, rendering them vulnerable to the development of new disabilities.

Box 2: Factors associated with development of postpolio syndrome

- Onset of functional deterioration after a prolonged period of stability
- Having had acute poliomyelitis at a young age
- Severe limb, bulbar, or respiratory involvement during acute polio
- Incomplete recovery with residual disability
- Greater physical activity during the intervening years
- Development of new symptoms or impairment associated with intercurrent events
- Devlopment of symptoms including:
  Pain in joints, bones, and muscles
  Fatigue
  Cramps, fasciculation
  Wasting, weakness
- Deterioration in functional abilities:
  Activities of daily living
  Mobility
  Upper limb function
  Respiratory function

Thus, new impairments often occur as a consequence of prolonged stresses on skeletal deformity and previously weakened muscles. Indeed, the extent of the original limb, trunk, respiratory, and bulbar weakness is an important factor in predisposing to the development of late functional deterioration (see box 2). Progressive wasting and weakness may occur in limbs already affected by poliomyelitis, and compensatory hypertrophy may occur in the contralateral limb because of weight bearing or distorted mechanics.[20] The effects of growth are important. Polio that developed before the growth spurt usually causes a progressive scoliosis and limb shortening, culminating in growth retardation.

Orthopaedic complications are extremely common and reflect the prolonged abnormal stresses applied to joints because of skeletal deformation and muscle weakness. Abnormalities include fixed flexion deformities, hyperextension or lateral instability of the knee or hip, progressive instability of joints, osteoporosis, fractures, osteoarthrosis, and scoliosis. Cervical spondylosis is manifest as neck pain, and variable radicular sensory symptoms or cord compression occur in some patients. Specialist orthopaedic assessment is necessary in planning appropriate management, but a range of simple supports to knee, ankle, and cervical spine or correction of worn and damaged aids can provide considerable functional improvement.

Respiratory insufficiency becomes evident as progressive nocturnal hypoventilation and may be due to chest wall deformity, progressive scoliosis, or other factors stressing critically compromised ventilation (including respiratory tract infections, obstructive airways disease, obstructive sleep apnoea, obesity, and pregnancy).[17] The strategies and methods of artificial ventilation used in poliomyelitis are long established, and indications for the use of long term domiciliary positive and, occasionally, negative pressure ventilation have been described.[21] Sleep disturbance with resulting fatigue may be a clue to the development of respiratory insufficiency, although it is important to remember that it may also indicate the presence of an independent sleep disorder such as restless legs syndrome.

Neurological complications often reflect skeletal deformity, and the use of callipers, crutches, and wheelchairs predispose to the development of peripheral nerve entrapment. A small proportion of patients may develop worsening dysphagia, which is not usually associated with other evidence of bulbar weakness, but this rarely progresses to aspiration. Other neurological disturbances have been reported to coexist with postpolio impairments, but there is no evidence to suggest these associations are anything but coincidental.[22 23]

Management

The effective management of postpolio functional deterioration requires a multidisciplinary approach involving both specific management of increasing impairment and a process of enabling patients to cope with new disabilities. Polio survivors are often extremely motivated and driven; they have conquered their disability, often by ignoring it completely, and have the most remarkable stories of achievement.[24] However, many continue to deal with increasing disability by intensive exercise regimens to regain muscle mass, strength, and function. Although some exercise is necessary to prevent wasting and stiffness from immobility, it is essential to strike a balance so that exercise regimens alleviate symptoms without causing increasing weakness and fatigue in damaged muscles.

The importance of muscular training is supported by randomised controlled trials and a considerable body of literature.[14 19] Graded exercise can improve symptoms of fatigue, weakness, and pain. Non-swimming exercise in warm water is often helpful in conditioning to exercise, improving mobility, and reducing pain. However, there is uncontrolled and anecdotal evidence that regular graded exercise should be broken up by regular periods of rest. Doctors must recognise that patients may note changes in function that are not manifest by increasing weakness on neurological examination. What seems, on examination, to be only a slight worsening of a severe disability may have devastating functional consequences to the patient.

Patients with impaired respiratory function should be closely monitored and be aware of the signs of a developing chest infection. They should have a prophylactic supply of antibiotics, receive flu and pneumococcal immunisation, and avoid smoking. Excess weight contributes to impaired mobility, development of osteoarthrosis, and respiratory insufficiency from hypoventilation and obstructive sleep apnoea. Weight loss is often difficult to achieve because of reduced mobility, and a dietician is an extremely important member of the management team. Managing pain can be difficult as it is often generalised and not localised to a joint or a limb. Simple physical measures such as warmth, cold, massage, and passive stretching may be of great value. Transcutaneous electrical nerve stimulation (TENS) and acupuncture are also helpful.

The British Polio Fellowship is an invaluable resource for patients and their families. It provides advice about rehabilitation, self management, welfare benefits, disability equipment, housing, and holiday accommodation.

Although there are no adequate longitudinal studies, experience suggests that postpolio functional

Additional educational resources

Useful websites for doctors

Polio Eradication (www.polioeradication.org)—the WHO website outlining the history of poliomyelitis and the present global strategy for polio eradication

www.polioeradication.org/casecount.asp —another WHO site containing detailed analysis of all worldwide reported cases of acute flaccid paralysis and acute poliomyelitis

Useful websites for patients

British Polio Fellowship (www.britishpolio.org)—charity providing advice and support for people who have had polio

Post-Polio Health International (www.post-polio.org)—important US organisation providing regular information about research, aetiology, and management of postpolio disability

Lincolnshire Post-Polio Network (www.ott.zynet.co.uk/polio/lincolnshire/)—extremely helpful resource centre established by a UK regional group with valuable and accurate links to relevant articles and clinical and research sites

deterioration does not necessarily progress once it has occurred. Fatigue and reduced mobility may often progress only slowly or stabilise. The prognosis will also depend on the nature of any underlying cause for the functional deterioration.[25]

Conclusions

Although some patients who have had poliomyelitis may later develop wasting, pain, and fatigue in isolation, in most there is significant underlying weakness and skeletal deformity predisposing to functional deterioration. The severe physical stresses of postpolio disability contribute to the development of progressive orthopaedic, respiratory, neurological, and general medical abnormalities, often exacerbated by intercurrent events. These abnormalities may present with atypical clinical features because of the extent of underlying atrophy and weakness, but many are potentially treatable and most patients can be helped to understand and manage increasing disability. It is essential to emphasise that the symptoms, disabilities, and impairments of postpolio functional deterioration are often amenable to treatment. It is also important to urge caution before attributing functional deterioration to a primary "postpolio syndrome" or "progressive postpolio muscular atrophy."

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Commentary: Postpolio syndrome—"We aren't dead yet"

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Alice is 58 years old and is married with two sons, both in their 20s. She works for several charities, is a magistrate, and is out most days and evenings. She fits in a gentle game of tennis every week, but cannot walk more than a mile, even on the level. This was not always the case. A few years ago, she was jogging at least three miles every day and playing squash several times a week. Gradually, she began to notice that jogging uphill became difficult. She tried to find more level routes. Climbing stairs became difficult, and her legs and back began to ache after exercise. This carried on for a couple of years. She realised that the aching was in three areas—her left arm, right leg, and back, the three places that had been most affected by polio when she was 12 years old. At that time, she had spent a month in hospital and then, after several years of taxing physiotherapy and exercises, she recovered completely, except for slight atrophy in one leg.

As she continued becoming weaker, she would suddenly find herself overwhelmed by exhaustion, which was relieved if she lay down for 15 minutes. She remembered an article about something called postpolio syndrome, which she had made a mental note of at the time but had thought nothing moreabout. Her general practitioner referred her to a neurologist, who said, "Nothing wrong with you." She mentioned postpolio syndrome, and he replied, "There's no such thing as postpolio syndrome."